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The Importance of Lenticel Infection of Apples by Penicillium Expansum

By

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[1] In cooperation with the State Committee on the Relation of Electricity to Agriculture.
[2] In cooperation with the United States Department of Agriculture.

The Importance of Lenticel Infection of Apples by Penicillium Expansum

Kenneth F. Baker[1] and F. D. Heald[2]

Introduction

The majority of workers have held the opinion that *Penicillium expansum*, the most important of the species causing blue mold decay of apples, is capable of gaining an entrance only through wounds, by entering the calyx canal, by growing down through the stem, or by establishment in necrotic spots. The prevalent belief regarding infection is expressed by Brooks, Cooley, and Fisher (4), "the germ tubes of blue mold spores are unable to penetrate the sound skin of the apple and must rely upon wounds as points of infection," but that "when a sound apple is smothered in the remains of a rotten one, the fungus is apparently able to penetrate the skin without the aid of a puncture." Morse and Lewis (13), Hesler and Whetzel (10), Coons and Nelson (5), Anderson (1), Fisher (7), Stevens and Hall (15), Cunningham (6), and other workers make similar statements.

Zschokke (16) reported that he had directly observed hyphae of *P. glaucum* penetrating the stomata of several varieties of apples and pears. "Ebenso gewähren die infolge der Oberflächenspannung zerrissenen Spaltöffnungen, sowie die aus gleichen Gründen entstandenen Risse neben den versteiften Haarnarben, Fäulnispilzen Einlass ins Fruchtfleisch und zwar namentlich dann, wenn nicht rechzeitig genügende Korkbildung stattfind." He concludes that for *P. glaucum*, "Das Mycelium der Fäulnispilze ist nicht imstande durch die intakte Epidermis in Kernobstfrüchte einzudringen, sondern bedarf dazu natürlicher oder künstlicher Offnungen". Kidd and Beaumont (11) state that "an analysis of the mode of entry of the fungus in a large number of rots caused by *P. expansum* shows that in the greater number penetration has taken place through the calyx end, or by means of the broken off stem, or by wounds such as insect punctures, and only rarely through a lenticel". The same workers later (12) reported 10, 10, 23, and 55 per cent of the rots due to Peni-

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[2] The writers wish to express their appreciation of the assistance of Mr. F. L. Overley, Associate Horticulturist, Wenatchee, in the obtaining and handling of the experimental lots of apples of Table 7. The Horticultural Inspection Office in Yakima and in Wenatchee very kindly assisted in obtaining some of the data on lenticel infection in commercial storage.

cillium species on lots of apples from calcareous soil, silt (old trees), silt (young trees), and fen soils, respectively, were due to infections through lenticels. Heald and Ruehle (9) reported 20 and 25 per cent lenticel infection with *P. expansum* in commercial lots of Delicious and Winesap apples of the 1930 Washington crop, with lesions varying from 1 to 8 per apple. Balakhonoff (2) reported that apples were easily infected by *Monilia fructigena* and *P. glaucum* through the apparently uninjured cuticle from which the natural waxy coating was rubbed off.

Zschokke (16) found that "sämtliche Pomaceenfrüchte in der Jugend deutliche Spaltöffnungen besitzen, welche zum Teil bis ins Alter erhalten bleiben (Quitte und viele Apfelsorten), zum Teil später zerschlitzen und zur Entstehung jener lentizellenähnlichen Korktüpfel auf den Früchten Anlass geben". The persisting stomata were largely on smooth-skinned apples; where they did not persist the splitting was found to occur either before or after the formation of underlying cork cells, and did not give rise to true lenticels with "Füllkork" except on apples with well-developed cork skin (e. g. French Lederreinette). Kidd and Beaumont (12) agreed with Zschokke in the manner of the formation of the lenticels, and found that the efficiency of the lenticel in gaseous exchange could not be determined by macroscopic examination or by size. From these facts it would seem that the word lenticel applied to apple fruit is inaccurate morphologically, but since the term is so generally used for the small corky spots it is used in this paper in the broader sense.

Lenticel infection not only is common in the case of many apple-rot fungi, but is the serious phase of such decays as *Neofabraea malicorticis, Gloeosporium perennans,* and *Sporotrichum malorum.* Kidd and Beaumont (12) report such infections by Polyopeus and Pleospora species as outstanding in this respect in England.

It is not difficult to understand why the belief that *P. expansum* is dependent on wounds for infection has persisted in the literature. Probably much of the data on blue mold decay has been compiled from inspectors' reports, with little critical examination of commercial stored lots. The tendency of large lesions to split, either from drying or from contact with other fruits, in a large percentage of cases makes it difficult and often impossible to ascertain the mode of entrance. The presence of conidial tufts, or of hyphal overgrowth under humid conditions, further obscure the true infection court. Many of the boxes examined showed that the decay was too far advanced to justify an accurate analysis of the infection court. Such lots were not tabulated. One must examine fruit before lesions have enlarged to any considerable degree in order to detect true cases of lenticel infection.

In this study data are presented which show that lesions from lenticel infections may be a very important part of the average one to three per cent loss every year, and of the high percentages of decay from

blue mold found in car lots on eastern terminals. Data that have been compiled from examination of different lots of apples in the Yakima and Wenatchee districts of Washington during the storage period show the relative importance of lenticel infection in lots with considerable decay.

Comparative Incidence of Blue Mold in Car Lots of Washington Apples at Eastern Terminals in Different Years

Blue mold is the principal cause of storage decay of apples in all countries from which we have reports. Rose (14) reported the results of inspections of boxed apples from the Pacific Northwest on the eastern terminals for the crop years 1917 to 1920. Inspection showed that 26.6 per cent of 233 cars of the 1917 crop averaged 7.5 per cent blue mold infection; 73.9 per cent of 219 cars of the 1918 crop averaged 13.0 per cent; 94.1 per cent of 2,084 cars of the 1919 crop averaged 7.6 per cent; 67.3 per cent of 1,138 cars of the 1920 crop averaged 6.0 per cent. Fisher (7) reported 23.7 per cent of 2,973 cars of the 1919 crop showing an average of 10.2 per cent decay and 60.6 per cent of 3,462 cars of the 1920 crop infected with blue mold at an incidence of 1 to 67 per cent. His figures were based on the crop of 26 states and Canada. Heald, *et al.* (8) summarized the inspection reports of Washington apples on eastern terminals for the 1925 and 1926 crops. The report for 1925 showed 37.8 per cent of 2,102 cars showing blue mold at an average incidence of 3.76 per cent. In the 1926 crop 40.8 per cent of 1795 cars were reported

Table 1. Results of Car Inspections of Washington Apples at Eastern Terminals, Crop of 1927.

Month of inspection	Number of cars showing blue mold	Average percentage of blue mold	Highest average percentage of blue mold in any car	Highest percentage of blue mold in any box	Number of cars without blue mold
Aug. 1927	—	—	—	—	—
Sept. 1927	5	7.6	14	25	37
Oct. 1927	64	4.8	55	80	138
Nov. 1927	63	5.5	50	85	240
Dec. 1927	95	3.03	16	35	161
Jan. 1928	147	2.9	25	40	174
Feb. 1928	183	2.5	18	50	146
March 1928	154	3.8	45	70	70
April 1928	155	4.28	25	70	21
May 1928	126	4.7	25	50	26
June 1928	63	7.0	20	86	8
July 1928	7	3.4	6	12	6
Total or average	1062	4.50	27.1	54.8	1027

showing blue mold in amounts averaging 3.65 per cent of the apples. In 1925 the "Highest average percentage of blue mold" averaged 24.36 for the year, in 1926 20.18; the "Highest percentage of blue mold in any box" averaged 45.72 for 1925, and 51.63 for 1926.

Similar records have been compiled for the crops of 1927, 1928, and 1929, and are presented at this time (Tables 1, 2, and 3).[1]

Table 2. Results of Car Inspections of Washington Apples at Eastern Terminals, Crop of 1928.

Month of inspection	Number of cars showing blue mold	Average percentage of blue mold	Highest average percentage of blue mold in any car	Highest percentage of blue mold in any box	Number of cars without blue mold
Aug. 1928	—	—	—	—	—
Sept. 1928	5	1.5	3	3	122
Oct. 1928	28	1.7	16	30	318
Nov. 1928	51	1.5	16	20	348
Dec. 1928	77	1.9	25	35	202
Jan. 1929	116	1.87	12	30	159
Feb. 1929	272	1.82	15	25	230
March 1929	220	2.95	65	80	159
April 1929	125	3.0	30	60	62
May 1929	191	4.7	27	60	15
June 1929	39	5.5	40	20	7
July 1929	4	5.3	20	20	0
Total or average	1128	2.88	24.4	34.8	1622

Whether the total annual loss is in proportion to the lots presented is questionable, as these figures form but a small part of the respective crops. Frequently apples of low quality are shipped without inspection at the point of origin, so that the percentages of loss for the entire crop may differ somewhat from the results shown by the inspections at eastern markets but would not be less than the figures so obtained.

The percentages of blue mold decay for 1917-1920 as recorded by Rose (14) are somewhat higher than the percentages of decay shown by the records from 1925 to the present. No records are available for the years 1921-1924, but it is apparent that there was a decrease during that period. Doubtless this reduction in incidence resulted from greater care in handling fruit, more strict grading with lessened numbers of injured

[1] Compiled under the direction of Mr. Frank G. Robb, Division of Fruits and Vegetables, Bureau of Agricultural Economics, from the records of the Federal Inspection Service.

Table 3. Results of Car Inspections of Washington Apples at Eastern Terminals Crops of 1929.

Month of inspection	Number of cars showing blue mold	Average percentage of blue mold	Highest average percentage of blue mold in any car	Highest percentage of blue mold in any box	Number of cars without blue mold
Aug. 1929	—	—	—	—	—
Sept. 1929	5	1.2	3	3	50
Oct. 1929	37	3.3	20	50	106
Nov. 1929	90	3.1	40	60	467
Dec. 1929	100	3.3	17	50	188
Jan. 1930	105	4.17	28	70	100
Feb. 1930	149	3.5	18	45	110
March 1930	193	3.7	33	50	78
April 1930	197	4.15	25	100	64
May 1930	147	4.5	45	65	43
June 1930	58	7.4	40	65	18
July 1930	5	3.0	4	10	0
Total or average	1086	3.75	24.8	51.6	1224

fruits occurring in the packed boxes, and to greater cold storage facilities with a lowering of common storage holdings. From 1925 to the present the losses have remained fairly uniform. It is apparent, therefore, that there is some factor entering into the blue mold problem that has not been affected by the changes and improvements in handling practices.

This hypothesis is further supported by an examination of the "Highest per cent of blue mold in any box" column of Tables 1, 2, and 3. A number of lots showed more than 50 per cent blue mold decay, and some were as high as 80 to 100 per cent. Heald, *et al.* (8) reported the same condition in the 1925 and 1926 crops. It would be difficult to explain such figures under the present high grading standards of the boxed Washington fruit on the basis of the four infection courts generally ascribed to this disease.

Incidence of Lenticel Infection by Blue Mold

During the last six years workers of the Washington Experiment Station have occasionally observed blue mold decay apparently centering at lenticels. Many specimens of the 1930 crop that showed clear cut lenticel infections were sent in for examination. Isolations from these lesions gave typical *P. expansum* colonies in all cases. During that year a few box lots from commercial holdings were also forwarded. The results of the examination of them are shown in Table 4.

The figures in the "Total decay" column are the percentages of fungous decay of all types in the given lots. "Lenticel infection" includes only lesions of a clear-cut type caused by blue mold centering at a lenticel and having no other visible place of entry. Those blue mold rots not showing any visible injury and being too wrinkled and overgrown with the fungus to allow being attributed to lenticel entrance are classed as of "Doubtful origin". Without question a large percentage of these

Table 4. Percentage of Decay in Box Lots of the 1930 Crop from Different Districts of Washington.

Variety	Locality where grown	Total decay	Blue mold decay		All other decay	Maximum lenticel infections per apple
			Lenticel infection	Doubtful origin		
Delicious	White Salmon	6.6	1.3	.6	4.7	1
Delicious	Yakima	20.0	20.0	0	0	2
Yellow Newtown[1]	Wenatchee	10.6	1.7	8.8	.1	1
Winesap	Prosser	25.0	25.0	0	0	8

[1] Examined February 24, 1931. All other lots examined January 12-24, 1931.

are enlarged lenticel infections, and for that reason these two columns should be jointly considered in arriving at an evaluation of the relative importance of such infections in stored apples. All blue mold decay not falling in either of these two groups (e. g. infections at injuries, calyx, or stem), and all other fungous decays, are included under "All other decay". This column does not give an accurate picture of the relative importance of blue mold and other fungous decays, since boxes from lots reported by inspectors as showing considerable blue mold decay were examined. In some lots decay by other organisms may be of greater importance than *P. expansum,* but in the crop as a whole it causes at least 75 per cent of the fungous decay (Brooks, Cooley, and Fisher, 4; Heald and Ruehle, 8). The figures of the column, "Maximum lenticel infections per apple," include only those caused by *P. expansum.* While in the majority of cases only one lesion was found per apple, 2 or 3 were common, and up to 14 were found. These terms are used in Tables 5, 6, and 7 in the same sense.

The figures in Tables 5 and 6 were obtained by examination of boxes selected at random from lots found by inspectors to show a high percentage of blue mold decay. Such random sampling is reported (Rose, 14) to give a truer estimation of the condition of the lot as a whole in the case of apples than with any other perishable fruit, possibly excepting citrus, and is the basis of federal and state inspection certificates.

EXPLANATION OF PLATES

Plate I.

A, Delicious apple showing typical lenticel infection in the early stage of development; B, Winesap apple showing three decay spots centering at lenticels, before splitting of lesions occurs.

Plate II.

Advanced stages of lenticel infection of Jonathan apples, showing wrinkling and shrinkage previous to splitting of lesions. A, No fungus growth is evident; B, Conidial tufts breaking through the central lenticel and in the surrounding area.

Plate III.

A, Winesap apples showing the splitting of comparatively small decayed areas and the subsequent fungus growth. In the tabular records such decay was classed as of "Doubtful origin." The lesions show the "bull's eye" effect so common in some lots; B, Winesap apple with larger lesion showing splitting. The arrow indicates the position of the lenticel through which infection occurred.

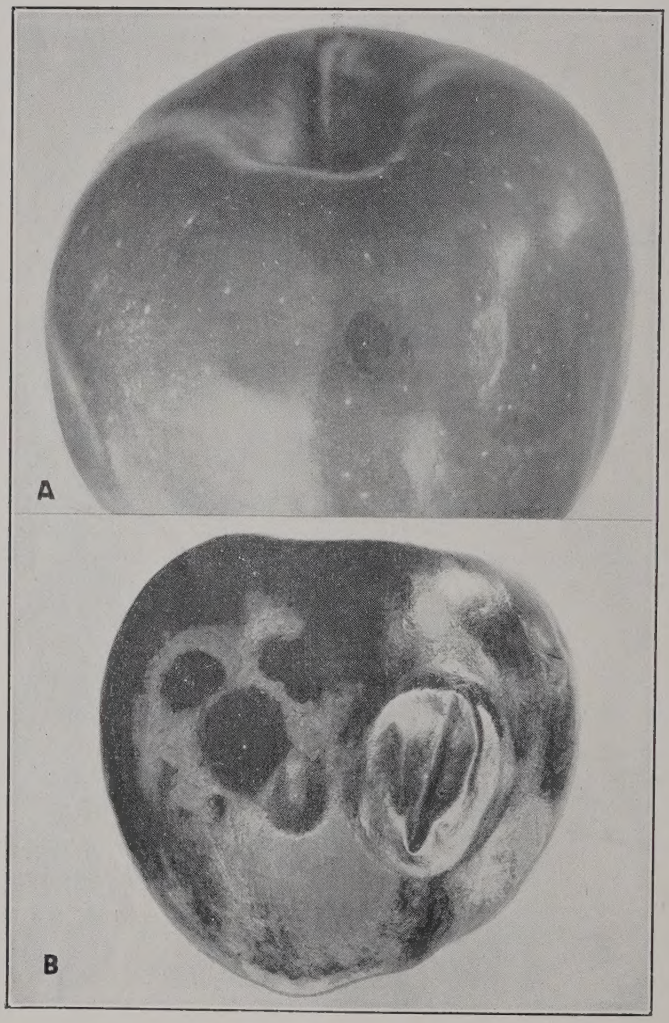

PLATE I.

Plate II.

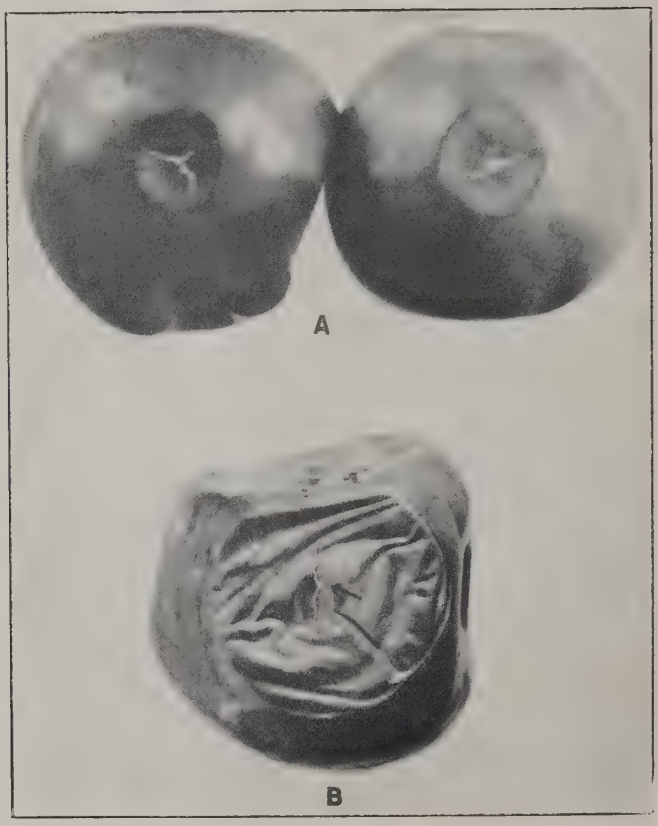

PLATE III.

When several boxes were examined the results were averaged and the number of apples examined was recorded. Thus the figures give a fairly accurate statement of the condition of the lots in question. While these examinations were of lots showing fairly high percentages of decay, the picture in lots with occasional decay is not essentially different. Lenticel infections have been found in such lots with considerable regularity.

Repeated isolations from rots of the lenticel infection type with the soft watery consistency typical of blue mold have given *P. expansum* in all cases. Isolations were made from all decays of which the causal organism was uncertain.

Several cold storage houses in Wenatchee were visited during the early part of February, 1932, and boxes taken at random from growers' lots showing high percentages of decay were examined. Only lots in which blue mold was found to be the principal cause of decay were recorded. The results are given in Table 5.

Table 5. Percentage of Decay in Different Lots of the 1931 Crop in Commercial Storage in Wenatchee, Washington. Examined February 2-4, 1932.

Variety	Grade[1] and size	Number of apples examined	Total decay	Blue mold decay		All other decay	Maximum lenticel infections per apple
				Lenticel infection	Doubtful origin		
Jonathan	F; 150, 163	276	7.2	2.1	1.8	3.3	1
Spitzenberg[2]	C; 72-125	297	8.0	.6	.6	6.8	1
Winesap	F; 198, 216	396	5.0	1.7	2.5	.8	1
King David	C; 113-163	550	25.8	1.0	.9	23.9[3]	1
Arkansas Black	EF; 88-125	514	1.5	.1	.1	1.3	1
Delicious	C; 88	88	10.2	2.2	2.2	5.8	1
Delicious[4]	C; 88	88	4.5	0	3.4	1.1	0
Delicious	C; 88	88	5.6	1.1	2.2	2.3	1
Delicious	C; 88	548	11.1	4.5	4.3	2.3	2

[1] EF, Extra Fancy; F, Fancy; C, C grade.

[2] This lot held in common storage. Remainder in cold storage.

[3] 15.4 per cent had entered through the stem. Due to the high percentage of decay this lot had been set aside for dumping, but the amount of decay was nearly as high at the time of condemning.

[4] In this lot no clear-cut lenticel infections were found, as decay had progressed far enough to place them under "Doubtful origin".

In the lot of the King David variety reported it is of interest to notice that 15.4 per cent of the decay was caused by blue mold entering through the stems, on which in most cases the fungus was forming an abundance of conidial tufts. The lesions spread outward in the stem

basin and were observed in all stages of invasion from a rotting of the stem to a complete decay of the fruit. This finding is further confirmation of the report of Barnum (3) on the stem invasion by blue mold.

Several Yakima cold storage plants were visited in the latter part of February, 1932, and random boxes of growers' lots showing high percentages of decay were examined. Only lots in which blue mold was found to be the principal cause of decay were recorded (Table 6). The lots mentioned in 3, 4, and 5 of the footnote were unopened random-sample boxes kindly forwarded to Pullman by the inspection force of Yakima for examination.

Table 6. Percentage of Decay in Different Lots of the 1931 Crop in Commercial Cold Storage in Yakima, Washington[1].

Variety	Grade[2] and size	Number of apples examined	Total decay	Blue mold decay		All other decay	Maximum lenticel infections per apple
				Lenticel infection	Doubtful origin		
Rome Beauty	F; 56-80	200	10.5	5.5	.5	4.5	2
Rome Beauty	F; 100, 113	153	26.7	16.3	3.9	6.5	14
Rome Beauty	F; 88	30	40.0	16.6	0	23.3	1
Rome Beauty	F; 56, 88	144	39.6	10.6	26.1	2.9	2
Delicious	EF; 88	88	32.9	23.8	2.2	6.9	5
Delicious	EF; 80	80	31.2	25.0	2.5	3.7	3
Delicious	C; 100	100	15.0	7.0	4.0	4.0	1
Delicious	C; 113	113	10.6	2.6	1.7	6.3	2
Winesap	C; 150	300	5.6	0	1.3	4.3	2
Winesap[3]	F; 113, 125	238	27.2	16.9	1.2	9.1	4
Winesap[4]	EF; 125	125	26.4	20.0	4.8	1.6	8
Arkansas Black[5]	F; 125	250	42.4	33.3	4.1	5.0	5

[1] Examined February 18-24, 1932, unless otherwise stated.
[2] EF, Extra Fancy; F, Fancy; C, C grade.
[3] Examined February 2, 1932.
[4] Examined April 15, 1932.
[5] Examined February 26, 1932.

The relative importance of lenticel infection is greater in this lot than in the Wenatchee series (Table 5). The lot of Rome Beauty with a maximum of 14 blue mold lenticel infections per apple showed numerous other fruits with 6 to 9 lesions of that type. The Arkansas Black variety had apparently been subjected to excessive temperatures in washing, as the majority of the apples had a characteristic bleached and scalded appearance.

An investigation was begun in the season of 1931 to determine the factors which influence the occurrence of lenticel infections. The results will be reported at a later time, but box lots from this series further show

the importance of lenticel infections. The fruit was not washed or graded except to remove any injured apples. They were dipped in a heavy suspension of *P. expansum* spores and dried before being packed. Aside from these variations the series was handled and stored as a commercial lot. The results obtained with some of the boxes of Jonathans and Delicious are shown in Table 7.

Table 7. Percentage of Decay in Packed Boxes of Experimental Lots of Wenatchee Apples of the 1931 Crop in Cold Storage[1].

Variety	Size	Total decay	Blue mold decay		All other decay	Maximum lenticel infections per apple
			Lenticel infection	Doubtful origin		
Jonathan	138	7.2	4.3	2.1	.8	1
Jonathan	150	6.6	2.0	1.3	3.3	1
Jonathan	150	6.0	.6	2.0	3.4	1
Jonathan	138	5.0	.7	3.6	.7	1
Jonathan	150	15.3	6.0	2.0	7.3	1
Jonathan	150	11.3	5.3	3.3	2.7	1
Jonathan[2]	138	7.9	5.7	.7	1.5	2
Jonathan	150	14.0	5.3	2.0	6.7	1
Jonathan	138	7.9	1.4	4.3	2.2	1
Jonathan[3]	138	11.5	5.8	5.7	0	1
Jonathan	125	9.6	6.4	1.6	1.6	2
Jonathan	138	7.9	3.6	3.6	.7	2
Jonathan	125	11.2	11.2	0	0	2
Jonathan	125	8.0	4.0	2.4	1.6	1
Jonathan	113	6.1	2.6	2.6	.9	1
Jonathan	125	4.8	4.0	0	.8	1
Jonathan[4]	125	52.0	46.4	3.2	2.4	3
Jonathan	125	19.2	15.2	0	4.0	3
Jonathan	125	21.6	16.0	0	5.6	3
Delicious	113	10.6	6.1	2.6	1.9	1
Delicious[5]	88	12.5	9.0	1.1	2.4	1
Delicious[6]	100	10.0	6.0	0	4.0	1
Delicious[5]	100	18.0	6.0	4.0	8.0	1
Delicious	100	6.0	3.0	1.0	2.0	1

[1] Examined January 17-20, 1932, unless otherwise stated.

[2] 45.4 per cent of decayed apples also with soft scald, though most of the decay was not centered on scalded areas.

[3] No soft scald on apples showing decay, but 15.2 per cent of it in the box.

[4] 44.6 per cent of decayed apples also with soft scald, though decay was not centered on scalded areas.

[5] Examined January 29, 1932.

[6] Examined January 22, 1932.

These figures further show the importance of lenticel infection in fruit decay. Three of the boxes showed soft scald, but only in two of these did it occur on the apples showing blue mold decay, and most of the infections did not center on scalded areas.

Apparently the commercial washing process is not an important factor in increasing the severity of lenticel infection, as the lots shown in Table 7 were not so treated though showing numerous infections of that type.

Characteristics of Blue Mold Lesions Originating from Lenticel

There is little difficulty in recognizing rots caused by blue mold entering the lenticels. The soft, watery, light brown decay of this organism is too well known to need description here. In early stages of lenticel infection small circular lesions centering very definitely on lenticels are seen (Plate I-A). Such lesions are shown in Plate I-B , the raised portions of the margins of the lenticel having been touched lightly with white ink to aid in photographing. In the early stages of decay, and in many older ones, no surface growth is evident (Plates I-B and II-A), but soon conidial tufts begin to emerge. Frequently the first external growth appears at the lenticel through which infection had obviously occurred; this growth usually precedes a more general emergence over the decayed area (Plate II-B). The presence or absence of these conidial tufts is dependent on the temperature and humidity of the storage. As the rotted area enlarges it becomes wrinkled and frequently irregularly sunken (Plate II-A). As a result of water loss and shrinkage the skin of relatively small lesions may split or crack through the center even before the fungus appears on the surface (Plate III-A). With continued loss of moisture, splits and cracks in the skin become more evident and are soon filled with the blue-green masses of the sporulating fungus (Plate III-B). The formation of conidial tufts in the central lenticel and other parts of the decayed area and the tendency of the older areas to split have doubtless been large factors in the failure to recognize the true importance of lenticel infections, as mentioned previously.

In many cases the decay may resemble the "bull's eye" type of rot when about one-half to three quarters of an inch in diameter. The central area may be a brown or deep tan with a lighter tan margin, a characteristic which is very common on Delicious. This lighter halo is especially noticeable in the area of the advance of the decay after removal to higher temperatures than cold storage. The Winesaps in Plate III-A show this zonation, although obscured somewhat by the radiating cracks. In early stages such " bull's eye" rot, not centering on a visible injury, may be mistaken for decays caused by *Gloeosporium perennans, Corticium centrifugum,* etc.

Discussion

Though scattered references to lenticel infection by *P. expansum* have occurred in the literature, the opinion appears to have prevailed that blue mold is essentially, if not wholly, a wound parasite. The difficulty of distinguishing between lenticel and wound infection in advanced stages of decay, due to splitting and shrinking of lesions and the characteristic formation of conidial tufts, has served to screen the true source of infection in many cases, and so to perpetuate the misconception.

If wounds occur in a fruit they are ordinarily an ideal infection court. Improved handling methods have greatly reduced the amount of injured fruit found in packed boxes, and should accordingly have cut down the amount of decay. With the reduction in the amount of injured fruit in packed boxes the percentage of decay has remained fairly constant, indicating that some other source of infection must be playing an important role.

From the data herein presented it is apparent that lenticel infection is one of the important causes of the one to three per cent annual loss from blue mold, and that it, rather than mechanical injury is the cause of many of the high percentages of blue mold decay showing in stored fruit.

Apparently there is little varietal difference in susceptibility to lenticel infection. To date it has been observed on the following varieties: Jonathan, Delicious, Winesap, Rome Beauty, Arkansas Black, Spitzenberg, King David, and Yellow Newtown.

Probably there are a certain number of lenticels on every apple through which gaseous exchange and water loss occurs, but whether these are the only ones capable of permitting entrance of blue mold is uncertain. Different lots of apples show great variation in the amount of lenticel infection present; some lots showing a high percentage of blue mold rot starting at injuries (indicating the presence of a considerable number of viable spores before the time of packing) do not show any considerable amount of infection starting at lenticels, while other lots have been found with up to 33.3 per cent of lenticel infection. Apparently there are some variable factors which affect the number of lenticels through which entrance occurs on a given apple. The nature of such lenticels, and of the factors tending to increase the incidence of lenticel infection, are being further investigated.

In the control of blue mold decay the principal measures that have been emphasized are sanitation and the prevention of injuries to the fruit. With the reduction of injuries to the present low level, it is not probable that much further reduction of decay will come from this quarter. There are three possible general methods for the reduction of lenticel infection by blue mold: (1) the modification of some factor or

factors in the cultural practices, the handling, or the storage of the apples which may be tending to increase the number of lenticels through which infection occurs; (2) the adoption of treatments tending to reduce the spore load of the fruit (e. g. sanitary practices in harvesting, cleaning, and packing); and (3) possibly the direct treatment of the fruit with some fungicide. Ultimate control may combine the various methods, but the second seems to offer the most hope, on account of the probable presence of a small number of lenticels as potential infection courts on apples under most conditions.

Summary

1. Blue mold (*Penicillium expansum*) is able to penetrate uninjured apples through lenticels much more commonly than has been reported in the literature.

2. Stricter grading requirements and improvements in packing equipment since 1925 would indicate a decrease in the amount of injured fruit in packed boxes. This hypothesis is not consistent with the fact that the annual loss from blue mold has remained fairly constant in these years.

3. Probably there are a certain number of lenticels on all apples through which infection can occur, but it is apparent that there are some factors, as yet unknown, which tend to increase the prevalence of such lenticels in some lots.

4. Lenticel infection may be responsible for a considerable portion of the average annual loss from blue mold decay, and may be the principal factors involved in lots of fruit showing high percentages of decay at eastern terminals.

5. Lenticel infection has been observed in eight varieties of apples, and doubtless occurs in all varieties under certain conditions. Differences in varietal susceptibility have not been observed.

6. The prevalence of lenticel infection may serve to modify somewhat the methods of control of blue mold, and may draw attention to factors other than the reduction of fruit injury in such control.

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